U. New Mexico

UNPUBLISHED PRELIMINARY DATA

GALACTIC HYDROGEN AS A HAZARD IN AURORAL SPECTROSCOPY

by

L. E. J. Montbriand
Defence Research Northern Laboratory
Ft. Churchill, Manitoba
Canada

B. A. Tinsley
Southwest Center for Advanced Studies
Dallas, Texas

A. Vallance Jones
University of Saskatchewan
Saskatoon, Canada

October, 1964

The research reported in this paper was supported in part by the Geophysics Research Directorate, Air Force Cambridge Research Center, Office of Aerospace Research under Contract AF19(628)-2829 and in part by the National Aeronautics and Space Administration under Grant NSG-279-62.

Accepted for publication in the Canadian Journal of Physics

GALACTIC HYDROGEN AS A HAZARD IN AURORAL SPECTROSCOPY

L. E. J. Montbriand
B. A. Tinsley
A. Vallance Jones

A B S T R A C T

17601

Hydrogen emissions from diffuse galactic nebulae in the Milky Way region have been found to interfere seriously at times with studies of the occurrence of auroral hydrogen emissions made with patrol spectrographs. Charts have been prepared in which the brightnesses of galactic hydrogen is plotted in galactic coordinates as contour lines of constant brightness in Rayleighs. This presents the information available from the astronomical literature in a form suitable for use in upper atmosphere spectroscopy.

Author

GALACTIC HYDROGEN AS A HAZARD IN AURORAL SPECTROSCOPY

1. Introduction

Since the discovery of the Balmer lines of hydrogen in the auroral spectrum by Vegard (1939) and the work of Meinel (1951) on the Doppler shift and broadening associated with these lines, they have been intensively studied. Experimental measurements have been made of the line profiles, the distribution of intensity with height and of the time and geographical variations of the hydrogen emission in relation to other features of the auroral spectrum.

Auroral spectroscopy is normally carried out with instruments having relatively large fields of view (rarely smaller than 2° x 2° and often much larger). The emissions of extra-terrestrial sources (with the exception of the moon, of course) averaged over such fields are usually negligible in comparison with the auroral emission features and indeed fall below the threshold of detectability of the spectroscopic instruments used. This is not the case however with the night airglow spectrum which is appreciably contaminated by a stellar continuum. Recently Dufay (1961) has shown that galactic Hα emission arising from regions of the Milky Way contaminates the Hα glow from fluoresence of hydrogen in the terrestrial exosphere (the geocorona).

Since diffuse gaseous nuclei emitting Hα lines are to be found in the Milky Way (Johnson, 1953), it is not surprising that emissions from such sources should also be capable of producing contamination of the hydrogen lines of auroral spectra. This contamination might be expected to become most serious when attempts are made to study the auroral line at low brightness levels with high sensitivity instruments, especially if the field of view is also restricted.

This paper records two cases in which the hydrogen emissions from galactic sources were recorded with auroral spectrographs at a level strong enough to be a source of serious confusion in the interpretation of the auroral spectrogram. The first instance occurred during a study of low-latitude aurora by two of the authors (B.A.T. and A.V.J.), while the second arose recently during the course of a synoptic study of the behavior of the hydrogen emissions from Churchill carried out by the third author (L.E.J.M.). Since these galactic hydrogen sources do under certain circumstances constitute a hazard in the interpretation of auroral spectra it seemed worthwhile to report the observations.

To assist in distinguishing galactic sources from auroral or geocoronal sources in other observations, charts were prepared from the data available in the astronomical literature. These charts show the brightness of galactic sources over the sky in a form suitable for auroral and airglow work.

2. Experimental

The southern hemisphere observations were made using the spectrograph described by Tinsley and Vallance Jones (1962). This instrument is a 2-in. grating spectrograph having a linear dispersion of 315Å/mm and a speed of f/1.1. The spectrograph was fitted with an objective lens focusing a vertical arc 24.5° of the sky on the slit. Spectra were obtained with the line of sight of the instrument centered at a point 18° west of south and at an elevation angle of 13° above the horizon. As part of a systematic study of the occurrence of auroral hydrogen lines at a low latitude station two exposures were taken from Christchurch, New Zealand each night during the period of darkness, one before midnight and one after. A typical pair of spectra obtained on the night of September 21/22, 1960 are shown in Fig. 1. A spectral slit width of about 30Å was employed. These spectra show, in addition to a diffuse feature along the whole length of the slit at about 6560Å a relatively strong segment of Hα emission for the pre-midnight exposure at two points on the slit which correspond with angles of 16° 45' and 20° 45' above the horizon. When it was found that identical features occurred in spectra taken on a series of clear nights and in view of the unlikelihood of any auroral emission being so strongly localized during an exposure lasting several hours, it was immediately suspected that some astronomical source was involved. One may deduce from the evidence presented in Fig. 1 that such a source would have to lie at a declination of about -59° 27' and -62° 51' and in a range of right ascension of 10 hours 40 minutes to 14 hours 10 minutes. In an attempt to obtain more precise information a series of 30 minute exposures were carried out with the same instrument on the night of October 6, 1960. The spectrograph with the same wide angle objective lens was pointed in the same direction. Hα emissions were observed corresponding to those of Fig. 1 on only two frames, namely those taken between 2005 to 2032 hours and 2033 and 2101 hours NZST. Transits of the stars β-Crucis and α-Centauri show up on the spectrograms and these were used to correct the celestial coordinates derived from the nominal coordinates of the line of sight. The results for the location of the sources are plotted on Fig. 2.

The instrument at Churchill was a spectrograph of the type described by Clark and Romick (1959). This instrument has a linear dispersion of 260 Å/mm, a spectral slit width of 25 Å and employs a 600 line/mm diffraction grating. A 64 mm f/0.71 Wray lens is used in the camera. This instrument has its slit oriented along the geomagnetic meridian and consequently variations along the spectral lines can be correlated with zenith distances of any sources crossing the meridian.

With this instrument similar recurrent isolated segments of Hα emission were observed in the spectrograms on several successive nights. This distinctive hydrogen emission was detected on fourteen occasions during August 1963. The remaining nights were either overcast or the effect was obscured by stronger auroral emissions. Fig. 3 shows a series of frames on which this recurrent hydrogen emission is recorded. Some aurora and auroral hydrogen is to be seen at low elevations in the south on these spectra. On Fig. 4 the time of occurence of this particular hydrogen is plotted for a period throughout September and August 1963; the times of the exposures on which the hydrogen was observed indicated by the horizontal bars. A straight line drawn through these observations has a slope corresponding to retardation of 4 minutes per day in the time of recording the emission. Since this is the difference between the sidereal and solar days it may be concluded definitely that the emission arises from an astronomical source. The celestial coordinates of this source were estimated to be $\delta = 75 \pm 2°$ and $\alpha = 21$ hrs. 0 minutes $\pm$ 10 minutes. The location of this source is plotted on a star map in Fig. 5.

Besides this rather localized source of hydrogen emission there seemed to be other more diffuse recurrent features appearing the the spectrograms.

An analysis of these was carried out using a total of 76 spectrograms obtained on eleven different nights in August 1963. These spectrograms were all free of auroral emissions. The results of this analysis are also plotted on Fig. 5 on which the squared-off regions indicate the coordinates corresponding to the regions which could have given rise to the observed recurrent hydrogen emissions and on which regions corresponding to particularly intense hydrogen emissions are indicated by cross-hatching. As a guide to the correlation of Fig. 5 with Fig. 3, parallel lines are drawn sloping from right to left from the top to the bottom of the diagram to correspond with the field of view of the spectrogram slit at different times on the night of August 11/12, 1963.

3. Discussion and Conclusions

From the data presented above it may be concluded without doubt that astronomical sources give rise to hydrogen emissions which are bright enough to be recorded on highly sensitive auroral spectrographs. The sources of the emissions observed in the southern hemisphere are probably gaseous nebulae which are known to emit the Balmer lines strongly and also are large enough to illuminate the slit of the spectrograph efficiently.

In an attempt to verify this conclusion and also to provide more complete data on the hydrogen emitting regions of the sky, charts were prepared from available astronomical data on celestial sources of Hα emission. The charts are drawn on the new galactic coordinate system, and in addition right ascension and declination coordinates for epoch 1950 are shown. Some approximate old galactic coordinates are shown also. The emission regions shown by Rodgers et al. (1960), Sharpless, (1953); Sharpless and Osterbrock, (1952); and Johnson, (1953) have been drawn on the charts.

Approximate brightnesses are shown. Contours have been drawn for 60 Rayleighs, 200 Rayleighs, and 600 Rayleighs. Regions between 60R and 200R are shown grey; regions between 200R and 600R are shown cross hatched, and regions above 600R are shown blackened. The broad areas of faint emission shown by Sharpless and Osterbrock (1952) apparently have intensities less than 60R, and are shown bounded by heavy dashed lines. The brightness data is taken from Johnson (1960), for the southern regions (Figs. 8 and 9) and where possible from Johnson (1953) for the northern regions (Figs. 6 and 7). In addition it has been possible to get a rough absolute brightness scale from the arbitrary brightness scale of Sharpless (1953), since his observing region overlaps that of Johnson (1960) in the range 1" = 350° - 40°.

Johnson's (1960) brightnesses must be obtained by subtracting a red continuum that can only be estimated from brightnesses in the yellow, and can give uncertainties of 100R or more. Johnson's (1953) brightnesses were obtained spectrographically, and may be incorrect by a factor of 2. In view of the uncertainties in the source material, and interpolation required in drawing new contours, the brightnesses shown on any position on the charts may be in error by a factor of 3. The 60R contour is the least accurate of the three shown.

Small Hα sources less than 1° in diameter have been drawn 1° in diameter and their brightnesses correspondingly reduced. If the brightnesses became less than 60R they were neglected. The survey of Sharpless (1953) extends only a few degrees either side of the galactic equator, and that of Rodgers, et al. (1960) extends to about 15° north and south. However the charts are drawn to cover ±24° of latitude, with Figure 8 extending to +30°, so that the emission regions around λ and θ Orionis and ζ Ophiuchi are included. Other emission regions, e.g. in the Magellanic clouds, may be present at latitudes outside the range ±15° in the region l" = 240° - 340° but no others are shown in the survey of Sharpless and Osterbrock (1952), which covers a wide area around the northern Milky Way. Comparison of Fig. 2 and Fig. 9 and Fig. 5 and Fig. 7 shows that in both cases the emissions detected by the spectrographs correspond to regions of celestial emission with brightness greater than 600R.

From the point of view of auroral spectroscopy the spectrograms show that the intensity of the galactic hydrogen can be as bright as or brighter than auroral hydrogen. This is shown clearly in Fig. 3 which show both auroral hydrogen and galactic hydrogen. For the spectrograms taken between 2330 and 2340, 2340 and 2350, and 0010 and 0020, the brightness of the galactic hydrogen emissions are greater or equal to the brightness of the auroral hydrogen. It is easy to imagine the possibility of drawing erroneous conclusions about the behaviour of the hydrogen lines in aurora if the two types of emission are not distinguished. Moreover this galactic hydrogen emission constitutes a background which can seriously hamper attempts to detect and study very faint proton-excited auroral hydrogen emissions from the upper atmosphere. This difficulty could be partly overcome by subtracting the galactic contribution as given in Figs. 6 to 9 from the intensities derived from the auroral spectrograms. Alternatively favorable orientations could be chosen for the instrumental lines of sight so that regions of galactic hydrogen emission would not be focussed on the slit. Unfortunately the latter requirement may conflict with the desire to monitor a particular strip in the upper atmosphere in cooperative synoptic studies.

ACKNOWLEDGMENT

The research reported in this paper was supported in part by the Geophysics Research Directorate, Air Force Cambridge Research Center, Office of Aerospace Research under Contract AF19(628)-2829 and in part by the National Aeronautics and Space Administration under Grant NSG-269-62.

REFERENCES

Clark, K. C. and Romick, G. J., J. Opt. Soc. Am., 49, 141, 1959.

Dufay, M., J. de Phys. et Radium, 22, 844, 1961.

Johnson, H. M., Astrophys. J., 118, 370, 1953.

Johnson, H. M., Mem. Mt. Stromlo Obsy. No. 15, 1960.

Meinel, A. B., Astrophys. J., 113, 50, 1951.

Rodgers, A. W., Campbell, C. T., Whiteoak, J. B., Bailey, H. H., and Hunt, V. O., "An Atlas of H-Alpha Emission in the Southern Milky Way." Mt. Stromlo Observatory, 1960.

Sharpless, S. and Osterbrock, D., Astrophys. J., 115, 89, 1952.

Sharpless, S., Astrophys. J., 118, 362, 1953.

Tinsley, B. A. and Vallance Jones, A., J. Atmos. Terrest. Phys., 24, 345, 1962.

Vegard, L., Nature, 144, 1089, 1939.

CAPTIONS FOR FIGURES

Fig. 1 Long-slit spectra of nightsky obtained from Christchurch, New Zealand, September 21-22, 1960. Angular length of slit 24.5°. The length of the slit lay in a vertical plane with the center of the line of sight of the spectrograph oriented S18° W at an elevation of 13°. The calculated declinations of astronomical sources crossing the slit are indicated. Spectrum a was obtained between 2030 and 2352 hrs. NZST and spectrum b between 0007 and 0430 hrs. The spectra of several stars crossing the slit are recorded. Spectrum a shows two segments of strong Hα emission at declinations of -59° 27' and -62° 51'.

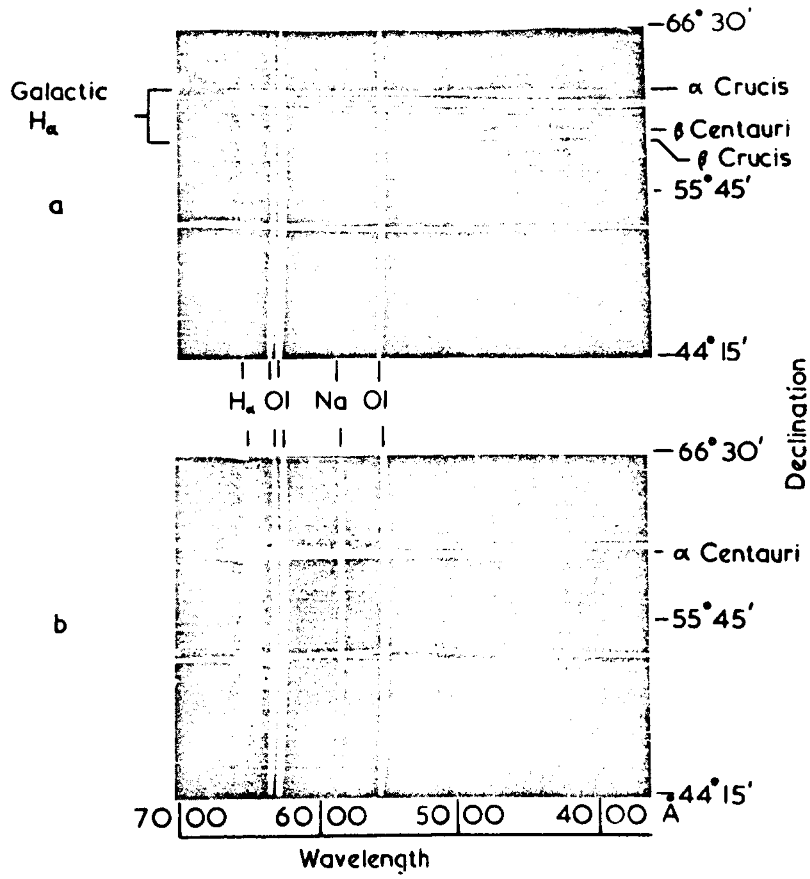
Fig. 2 Star map showing the regions from which the Hα emissions of Fig. 1 must have originated. These regions which are indicated by the cross-matched rectangles were deduced from the exposures of Fig. 1 and also from a second set of 30-minute exposures as described in the text. The probable sources, diffuse galactic nebulae, lying within these regions are indicated as solid discs. On this map also are plotted the images of the spectrograph slit on the sky for the beginnings and end of the exposures shown in Fig. 1.

Fig. 3 Patrol spectrograms obtained at Churchill, Manitoba for the night of August 11/12, 1963. Segments of galactic Hα are marked.

Fig. 4 Plot of the time of appearance of the segment of Hα which appeared between 0010 and 0020 hrs. CST in Fig. 3 on succeeding spectra taken later in August and September, 1963.

Fig. 5 Star map showing the Hα emitting regions of the sky as observed from Churchill. The boundaries of the Milky Way are indicated by the dashed line while the regions within which Hα emission was observed outlined by the solid line of "histogram-like" appearance. The regions of particularly strong Hα emission are shaded. Lines of declination and right ascension are indicated as also are the lines showing the image of the slit on the sky for different times on August 11/12, 1963.

Figs. 6 to 9 Brightness contours of celestial Hα emission derived from the astronomical literature as described in the text.



Galactic H_α
a
b
−66° 30′
α Crucis
β Centauri
β Crucis
55°45′
−44° 15′
H_α OI Na OI
−66° 30′
α Centauri
−55°45′
−44° 15′
Declination
7000 6000 5000 4000 Å
Wavelength

FIGURE 1

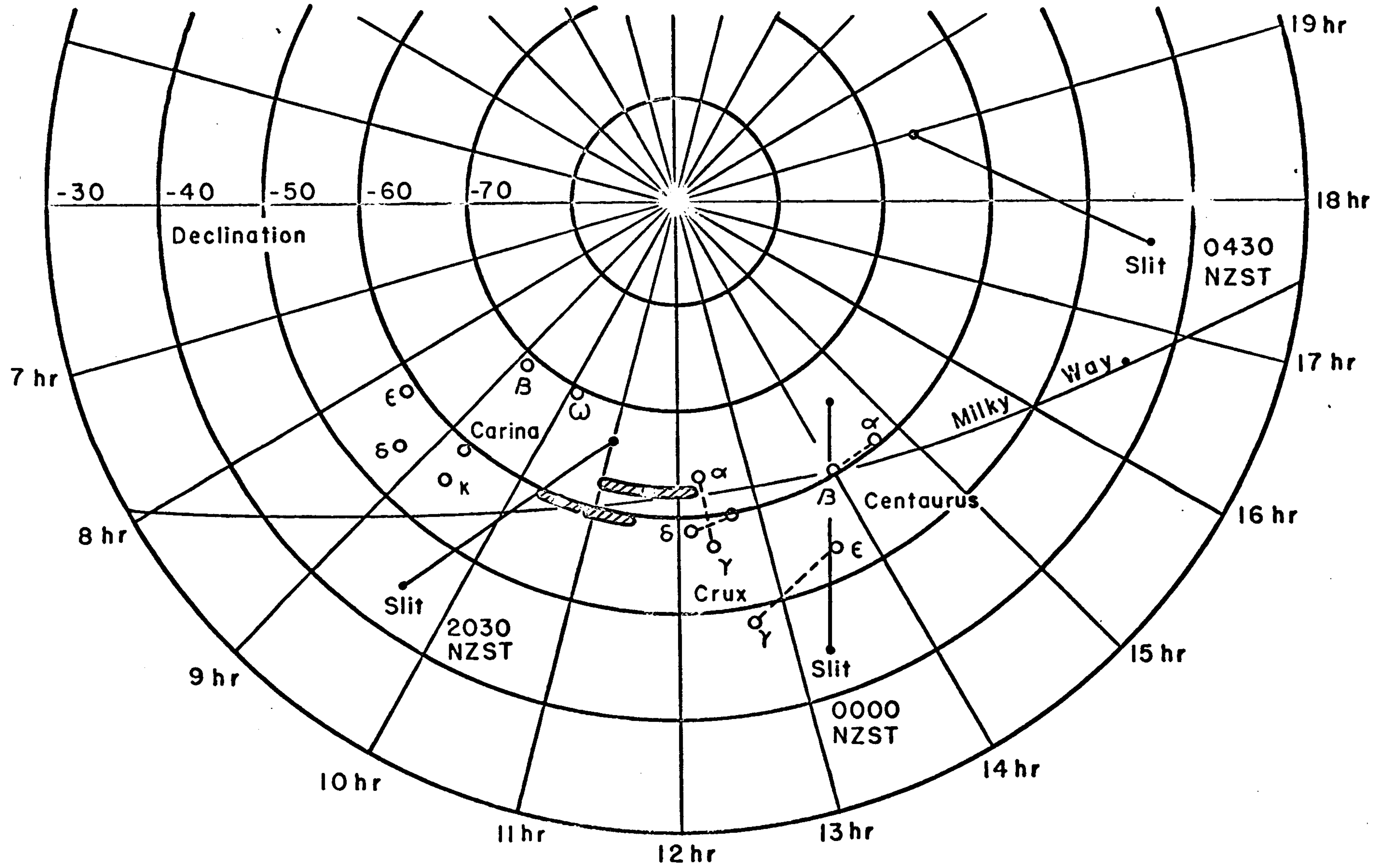

-30
-40
-50
-60
-70
Declination
7 hr
8 hr
9 hr
10 hr
11 hr
12 hr
13 hr
14 hr
15 hr
16 hr
17 hr
18 hr
19 hr
Carina
Crux
Centaurus
Milky
Way
Slit
2030
NZST
Slit
0000
NZST
Slit
0430
NZST
Right Ascension

FIGURE 2

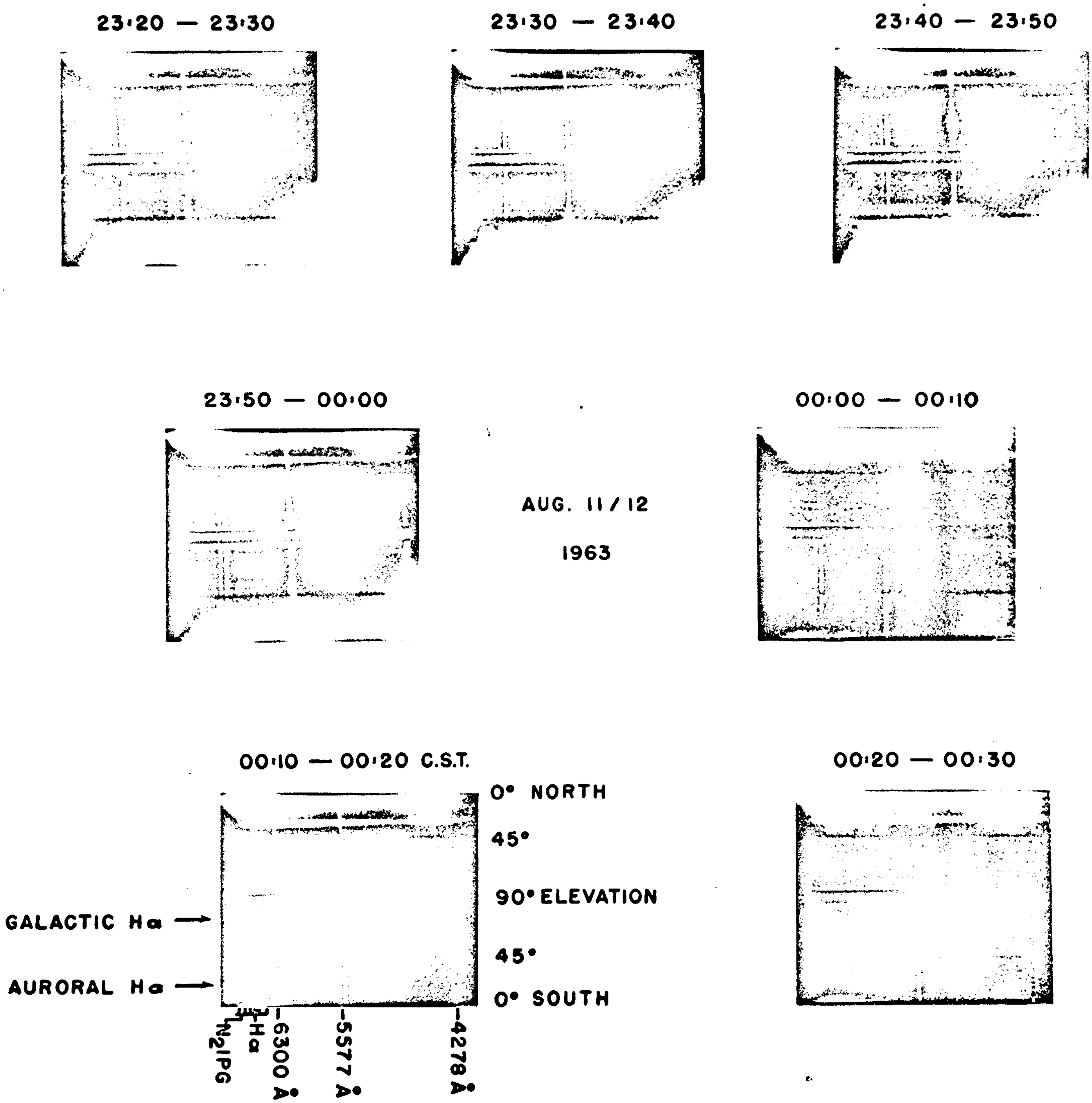

23:20 — 23:30
23:30 — 23:40
23:40 — 23:50
23:50 — 00:00
AUG. 11 / 12
1963
00:00 — 00:10
00:10 — 00:20 C.S.T.
0° NORTH
45°
90° ELEVATION
45°
0° SOUTH
GALACTIC Hα
AURORAL Hα
N2 IPG
Hα
6300 Å
5577 Å
4278 Å
00:20 — 00:30

FIGURE 3

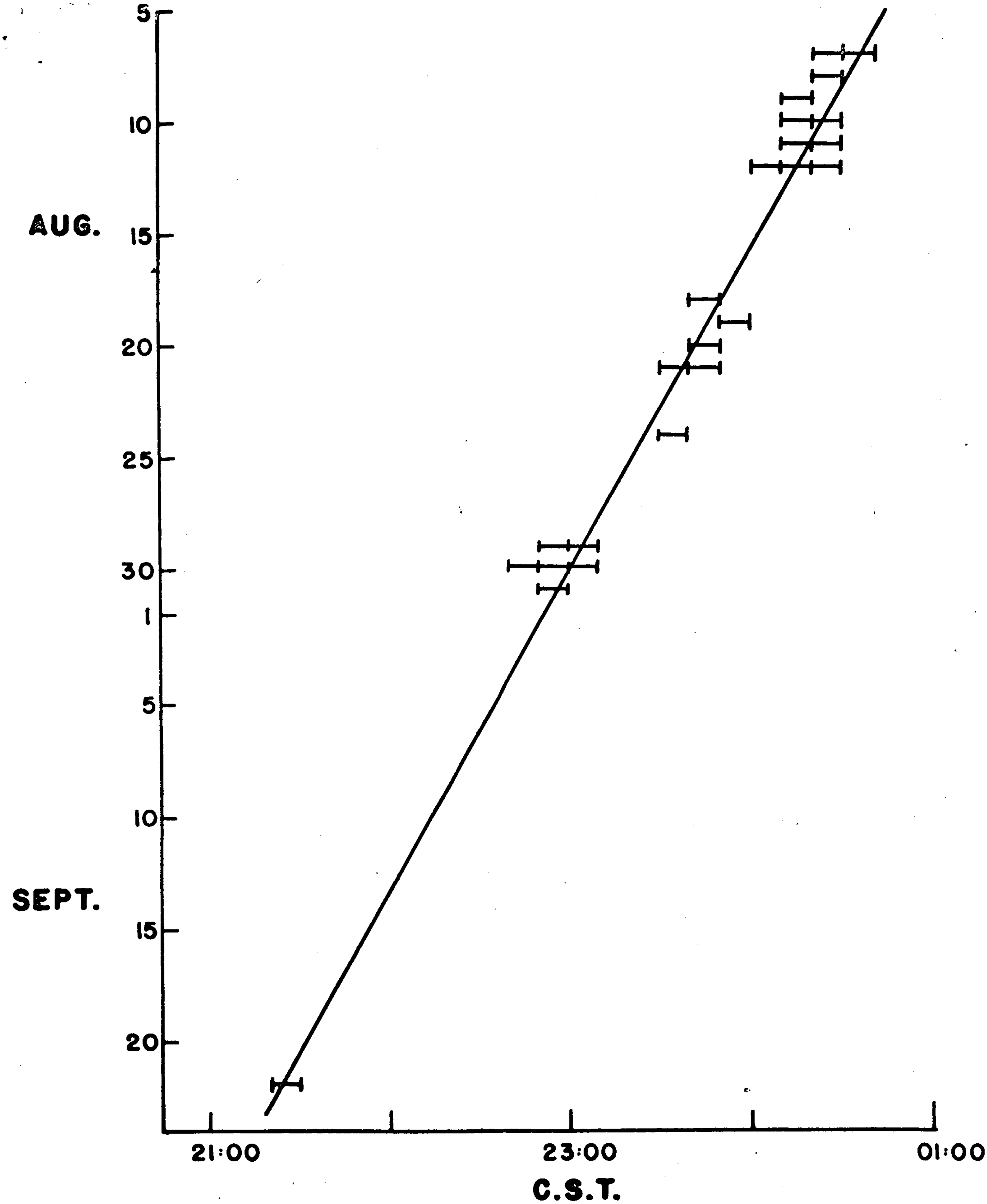


FIGURE 4

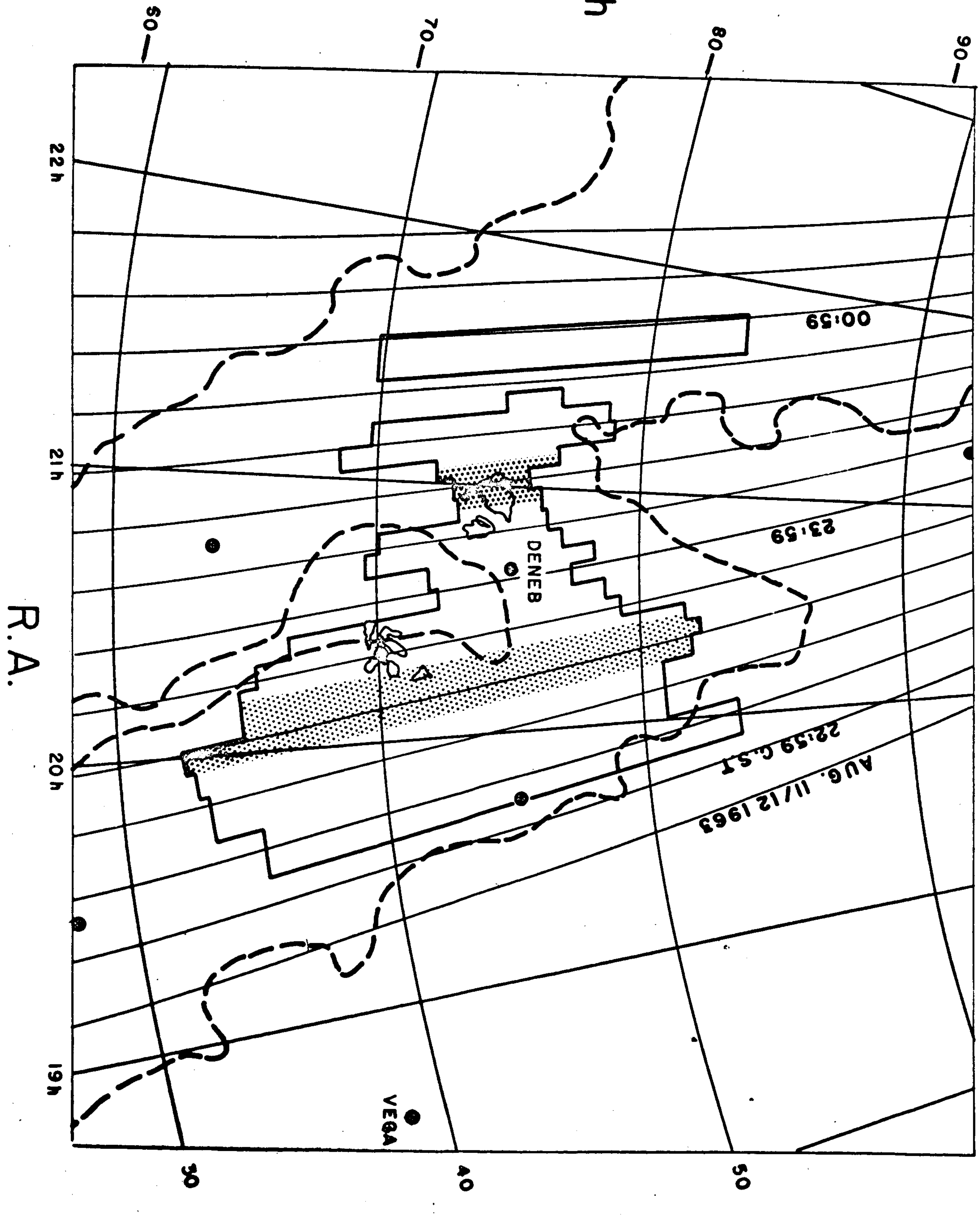

h
90
80
70
50
22h
21h
20h
19h
30
40
50
00:59
23:59
22:59 C.S.T
AUG. 11/12 1963
DENEB
VEGA
R.A.

FIGURE 5

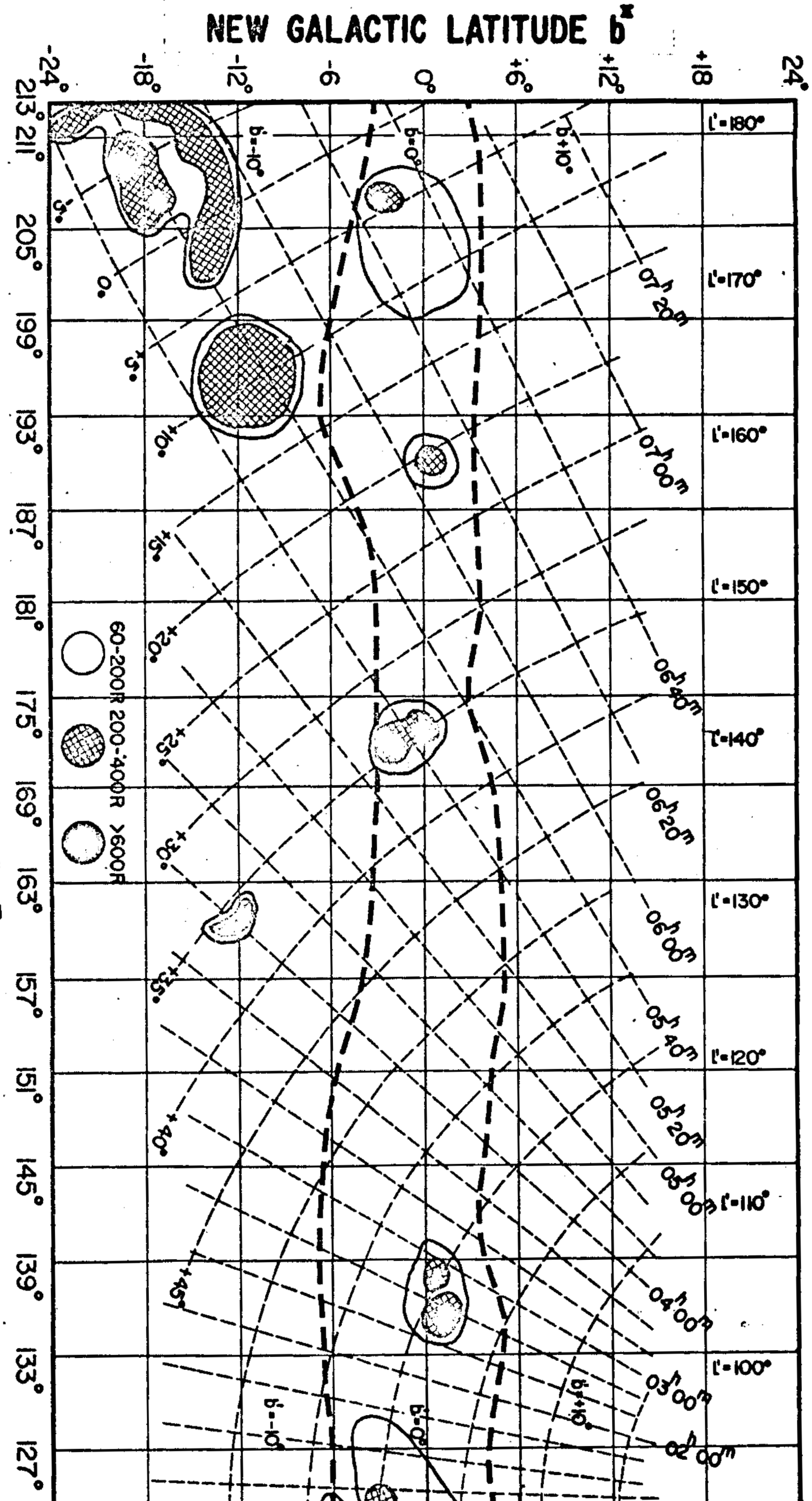

NEW GALACTIC LATITUDE b^{II}
NEW GALACTIC LONGITUDE l^{II}
60-200R
200-400R
>600R

FIGURE 6

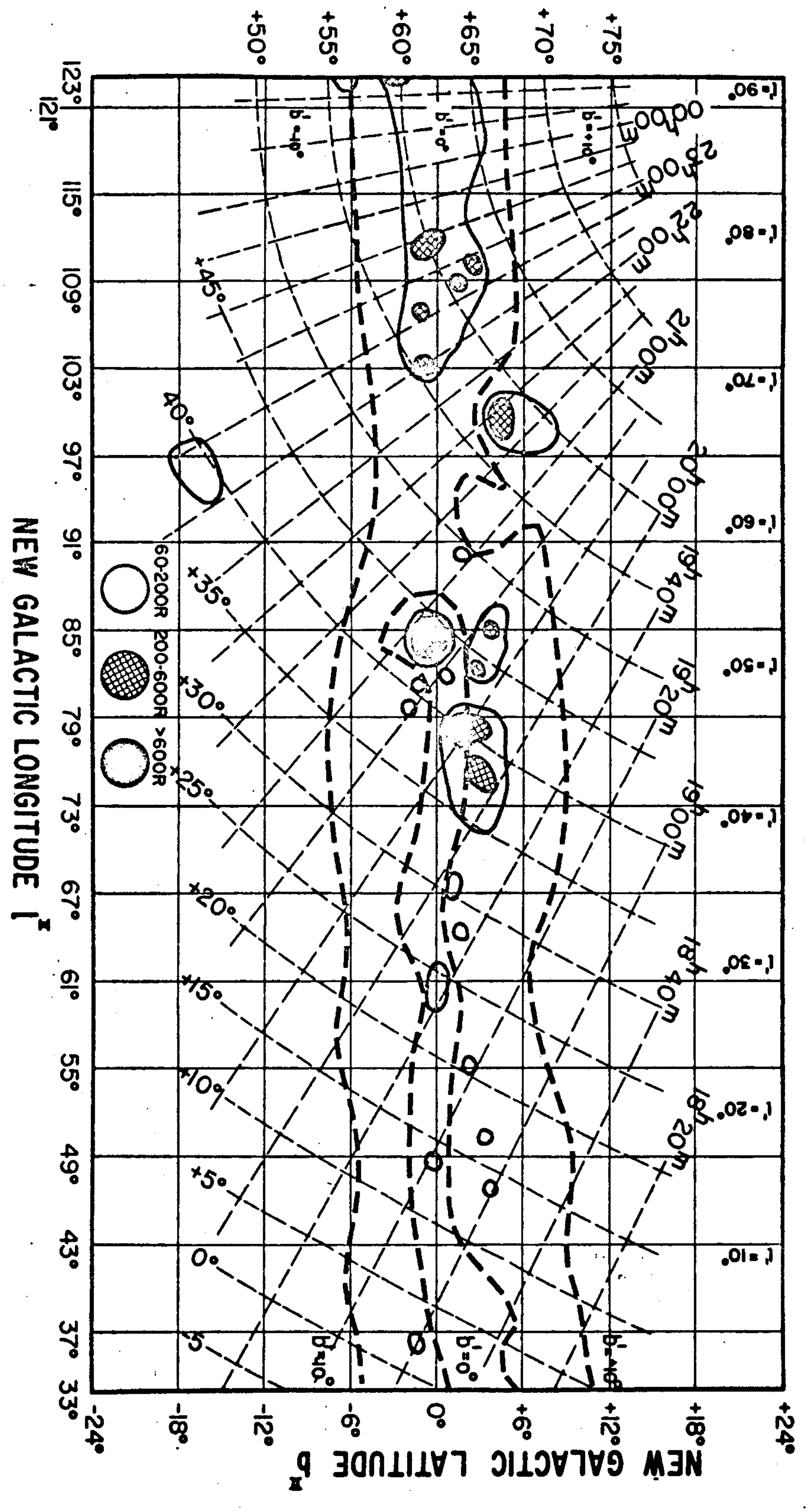

NEW GALACTIC LONGITUDE l^{II}
NEW GALACTIC LATITUDE b^{II}
60-200R
200-600R
>600R

FIGURE 7

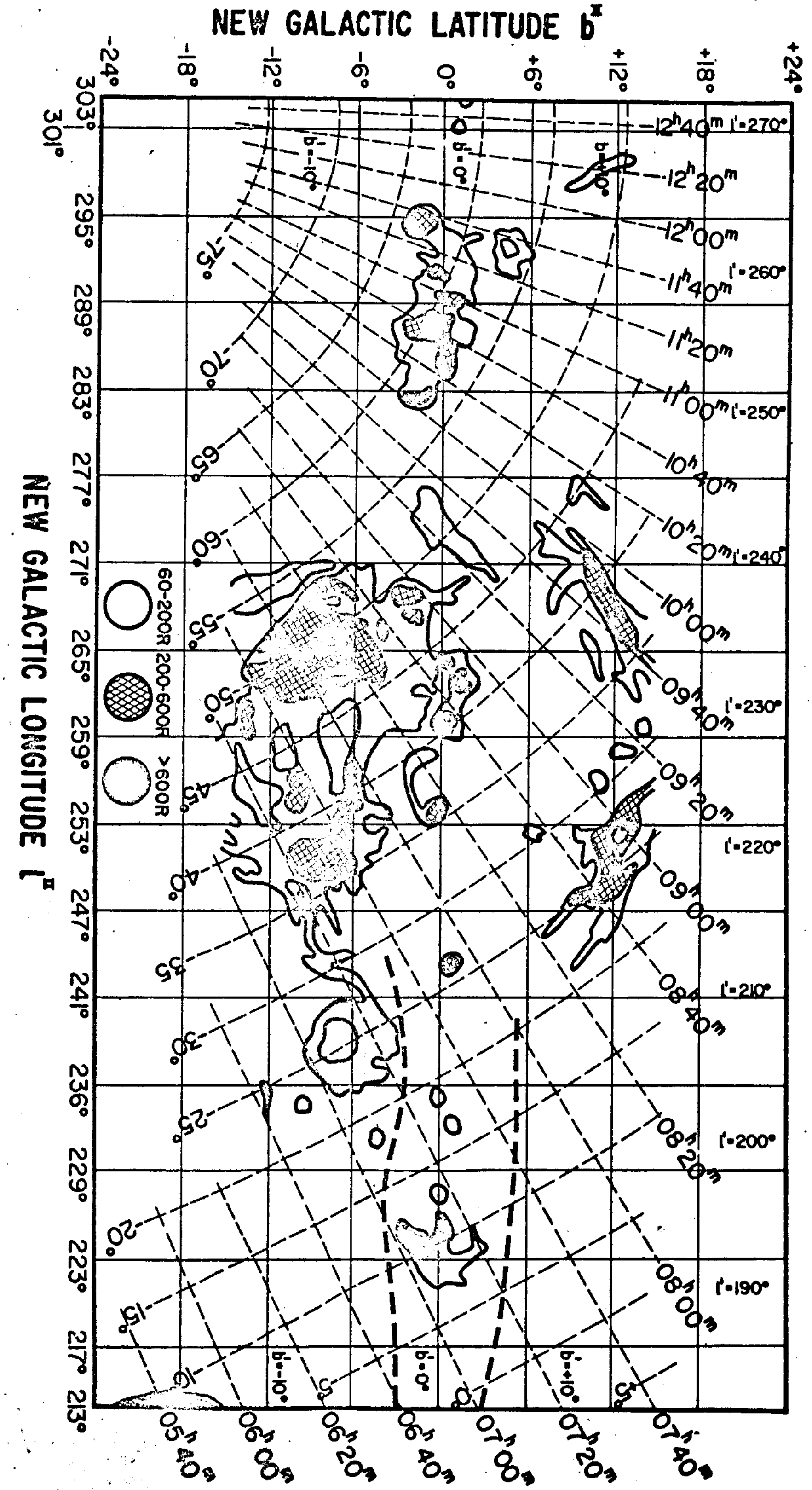

NEW GALACTIC LATITUDE b^{II}
NEW GALACTIC LONGITUDE l^{II}
60-200R
200-600R
>600R

FIGURE 9